REINFORCEMENT OF PLASTIC USING EMPTY FRUIT BUNCH (EFB) OF PALM OIL WASTE

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ABSTRACT

The use of natural fiber as a reinforcement in polymer composites are getting so much attention and widely used for technical application in automotive , furniture, aerospace ,packaging and others industries. demand and attraction for alternatively material from renewable resource are incredibly increased. Awareness the come out from precision analysis in many aspects for example safety, environmental impact, health and cost saving for composites production had produce one new idea in finding an alternative way to replace the limited resource material like synthetic material. The environmental issue and lower cost for natural fiber and lignocelluloses resource had attract many researcher in the entire world to make this materials as a reinforce material in composite engineering. The main resource is get from agriculture sector that produce as a waste like grain husk, pineapple leaves, kenaf, jut and coir. The objective of this research is to determine the effect of alkaline treatment on this fiber, to produce high quality fiber by treatment process and to find the effect of natural fiber reinforcement with epoxy (plastic).Method that was used in making these plastic reinforcement composites are thermosetting process where the liquefy epoxy resin will be combine with empty fruit bunch (EFB) of oil palm fiber with hot press equipment. The empty fruit bunch fiber will be treat first with alkaline treatment to remove the lignin contain and increase the surface roughness. Alkali treatment also can make fiber more hydrophobic in order to get good interfacial adhesion between fiber and thermoset polymer matrix. The resulted are 10% treatment with NaOH give the best result from effective and economic side where provide tensile strength of 14.9 MPa for 10% fiber loading where it can be used for structural applications.

ABSTRAK

Penggunaan serat alam sebagai penguat dalam komposit polimer mendapat begitu banyak perhatian dan banyak digunakan untuk aplikasi teknikal di otomotif, furnitur, aerospace, bungkusan dan industri lain. permintaan dan daya tarikan untuk bahan alternatif dari sumber daya terbarukan yang sangat meningkat. Kesedaran keluar dari analisis precision dalam banyak aspek keselamatan contohnya, kesan persekitaran, kesihatan dan penjimatan kos pengeluaran komposit telah menghasilkan satu idea baru dalam mencari cara alternatif untuk menggantikan bahan sumber daya terbatas seperti bahan sintetik. Isu persekitaran dan kos yang lebih rendah untuk serat alam dan sumber daya lignocelluloses telah menarik banyak penyelidik di seluruh dunia untuk membuat bahan ini sebagai bahan menguatkan teknik komposit. Sumber daya utama adalah mendapatkan dari sektor pertanian yang menghasilkan sebagai sisa seperti kulit gandum, daun nenas, Kenaf, unjuran dan pad. Tujuan dari penelitian ini adalah untuk menentukan pengaruh perlakuan alkali pada serat ini, untuk menghasilkan serat berkualiti tinggi oleh proses rawatan dan untuk mengetahui pengaruh penguat serat alami dengan epoxy (plastik). Kaedah yang digunakan dalam membuat komposit plastik thermosetting penguatan proses dimana mencairkan epoksi resin akan menggabungkan dengan tandan buah kosong (TKS) dari serat kelapa sawit dengan peralatan tekan panas. Serat tandan buah kosong akan memperlakukan pertama dengan perlakuan alkali untuk menghilangkan lignin mengandung dan meningkatkan kekasaran permukaan. perlakuan alkali juga boleh membuat lebih banyak serat hidrofob untuk mendapatkan adhesi antar muka yang baik antara serat dan matriks polimer termoset. Adalah perlakuan tersebut menghasilkan 10% dengan NaOH memberikan hasil yang terbaik dari sisi ekonomi yang berkesan dan mana memberikan kekuatan tarik 14,9 MPa selama 10 loading% serat di tempat yang boleh digunakan untuk aplikasi struktur.

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LIST OF ABBREVIATIONS & SYMBOLS

%	-	Percentage
wt%	-	Weight percent
cm	-	Centimeter
DP	-	Degree of polymerization
g	-	Gram
kg	-	Kilo Gram
kN	-	Kilo Newton
m	-	Meter
ml	-	Milliliter
mm	-	Millimeter
N	-	Normality
NaOH	-	Sodium Hydroxide
OH	-	Hydroxide
ºC	-	Degree Celsius
Pa	-	Pascal
TAPPI	-	Technical Association of the Pulp and Paper Industry
V	-	Volume
SEM	-	Scanning Electron Microscopy

CHAPTER 1

1.1 INTRODUCTION

The use of natural fiber as a reinforcement in polymer composites are getting so much attention and widely used for technical application in automotive , furniture, aerospace ,packaging and others industries. Biomass resource from natural fiber is a renewable and easy to get in a lower price compare to synthetic fiber. It has potential to replace the higher cost synthetic fiber like glass fiber, boron, Kevlar and others (bledzki & Gasan , 1999). Lignocelluloses fibers are used as alternative to glass fiber as a reinforcement material in composites has attractive many researchers in this field. That is because the natural fiber offer several of advantages compare to glass fiber from lower cost, 'high performance/weight', lighter, easy to process, reactive surface to chemical reaction other than been burn if it is not used anymore.(HPS Abdul khalil et,. 2001). One of lignocelluloses material that is very important with Malaysia scenario is waste from palm oil production industries because Malaysia produces more than 17 million tons of EFB annually. One of the major waste from this industries are empty fruit bunch (EFB).EFB are produced as a side product after the seed is pulled out from it bunch for oil extraction process (Thomas et. Al,. 1997). All the components from palm oil have several potential in many fields for example like plastic-palm oil component (Rozman et al,. 2001), rubber-palm oil components (Ismail et. Al,. 2000). pulp and paper. With advantages those natural fibers have, composites industries from thermoset and thermoplastic are fast develop and increasing.

1.2 Problem Statement

1.2.1 Demand for alternatively material

Lately, the demand and attraction for alternatively material from renewable resource are incredibly increased. Awareness the come out from precision analysis in many aspects for example safety, environmental impact, health and cost saving for composites production had produce one new idea in finding an alternative way to replace the limited resource material like synthetic material (Torres & Cubillas, 2005).Environmental problem such as global warming, energy consumed and desire to produce products from natural resources embody an interest and demand for plant based products (Reddy & Yang, 2005). From research that had been done, we know that plant is very interesting subject when we analyze as a material for composites aspects because products from this resource will give the better and various characteristic that we need.

1.2.2 Environmental issue

Influence from the consumed of synthetic fiber that give many problem such as bad impact to the environment also contribute to this revolution. Even though this synthetic fiber had give many benefit to consumer, this composites also give effect to the environment through their production process .For example, the production of glass fiber are strong depend on fossil fuel where the burning process will let free a large amount of CO_2 to the atmosphere . Green house effect is a phenomenon that happen as a result from CO_2 release that produce from fuel burning (eg ; petroleum). This situation is clearly different with natural co2 for lignocelluloses fiber where it more interesting and give benefit to the environment (Paul et al., 2003).

The environmental issue and lower cost for natural fiber and lignocelluloses resource had attract many researcher in the entire world to make this materials as a reinforce material in composite engineering. The main resource is get from agriculture sector that produce as a waste like grain husk, pineapple leaves, kenaf, jut and coir.

1.3 Research Objectives

1. To determine the effect of alkaline treatment on this fiber.

2. To produce high quality fiber by treatment process.

3. To find the effect of natural fiber reinforcement with epoxy (plastic).

1.4 Scopes of Study

1. To apply the thermosetting process in plastic composite production like those we know, plastic manufacturing process fall into duple that is thermoplastic and thermosetting. Both of the processes have different method and their own type resin. So in my research I want to discover the thermosetting process.

2. To discover how to make good quality fiber by alkaline treatment process. From previous research, alkaline treatments have proved that it can bring good effect to the fiber propertie

1.5 Rationale and Significance.

Trough my research I hope it will be give a new information to the community and also giving benefit to IKS (medium and small industries) that want to find new alternative raw material that is cheaper and easy to get in Malaysia especially in polymer industries. It also will give new added value to industrial agriculture industries wastes especially palm oil waste.

1.6 Research background

1. As we know there are two type of process in making the composites which are thermosetting and thermoplastic .Every process have their own method and machine to produce the composites. Both processes also use different polymer for example thermosetting use epoxy as matrix that are in the liquid form but thermoplastic are using polyethylene that are in solid form. So in my research I will apply thermosetting process for composites.

2.Alkaline treatment have been applied in many treatment process for fiber.The different between my research and the previous research are combination of fiber treatment NaOH with 5%, 10% and 15% concentration and bleaching process with H_2O_2.

CHAPTER 2

2.0 LITERATURE REVIEW

2.1 Composite Material

A dictionary defines a composite as something made up of distinct parts or constituent. At the atomic level material such as some metal alloys and polymeric materials could be called composite materials since they consist of different and distinct atomic groupings. A composite material is a materials system composed of a mixture or combination of two or more micro or macro constituents that differ in form and chemical composition and are essentially insoluble in each other (bledzki & Gasan , 1999). Newer materials and composites that have both environmental and economic benefits are being developed for applications in the automotive, building, furniture and packing industries. Agro and forest resources have always played an important role in the plastic industry. A composite is a structural material which consists of combining two or more constituents or material that is different from common heterogeneous material. A composite is considered to be any multiphase material that exhibits a significant proportion of the properties of both constituent phases such that better combination of properties is realized. The constituents are combined at a macroscopic level and are not soluble in each other. One constituent is called the reinforcing phase and the one in which it is embedded is called the matrix. Composites may be selected to give unusual combination of stiffness, strength, weight, high temperature performance, corrosion resistance hardness, conductivity or cost effectiveness. The combination of the polymers is classified as Figure 2.1. Composites can be classified into roughly three or four types according to the filler types:

• Particulate

• Short fiber

• long fiber

• laminate

Short and long fiber composites are composites in which the filler material has a length to diameter ratio, l/d, greater than one. Short fibre composites are generally taken to have l/d of ~100 while long fiber type would have l/d ~ ∞. Fiber glass filler for boat panel is an example of short fiber composite. Carbon fiber, aramid fiber (Kevlar®) fibers are some of the filler material used in the long fiber type composites.

Laminate is the type of composite that uses the filler material in form of sheet instead of round particles or fibers. Formica countertop is a good example of this type of composite. The matrix material is usually phenolic type thermoset polymer. The filler could be any material from craft paper (Formica) to canvas (canvas phenolic) to glass (glass filled phenolic).

Since the composites are non-homogeneous, the resulting properties will be the combination of the properties of the constituent materials. The different type of loading may call on different component of the composite to take the load. This implied that the material properties of composite materials may be different in tension and in compression as well as in bending.

2.2 Natural Fibers

In recent years, the use of natural fibers as reinforcement is increasingly replacing the conventional inorganic fibres in polymer matrix composites. Natural fibers have recently attracted the attention of scientists and technologists because of the advantages that these provide over conventional reinforcement materials, namely, low cost, low density and high specific properties and bio-degradable characteristic. But high level of moisture absorption, poor wettability and insufficient adhesion between untreated natural fibres and the polymer matrix leads to debonding with age. Conventional fibers, like glass and carbon fibers can be produced with a definite range of properties, whereas the properties of natural fibers vary considerably depending on the fiber diameter, structure (e.g. proportion of crystalline fibrils and non crystalline region, spiral angle), supramolecular structure (degree of crystallinity), degree of polymerization, crystal structure (type of cellulose, defects, orientation of the chains of non crystalline cellulose and crystalline fibrils), void structure (pore volume, specific interface, size of pores) and finally whether the fibers are taken from the plant stem, leaf or seed and on growing conditions. To improve the properties of the composites, the natural reinforcing fibres can be modified by physical and chemical methods. Natural fibers that have been evaluated as replacements for glass and other non recyclable fibers include flax, hemp, kenaf and sisal. These natural fibers can be split into two categories bast and leaf. The bast fiber composites include kenaf and flax, while sisal may be considered a leaf fiber. The bast exhibit a superior flexural and modulus of elasticity (MOE), but the leaf fibers show superior impact properties.

Compared to glass fibers, the bast fibers tend to show approximately the same flexural strength and a higher MOE. The main drawback in using these natural fibers is the hydrophilic nature of the natural fibers, which may lead to problems of adhesion with the hydrophilic polymer matrix. High temperatures must also be avoided due to the possibility of fiber degradation. In addition, since they are grown naturally, the properties of the fibers can vary immensely from plant to plant (HPS Abdul khalil et,. 2001).

2.2.1 Oil Palm

One of the materials of this category that is of great relevance to the world and Malaysia in particular is the large quantity of biomass generated by palm industries. Oil Palm or Elais guineensis was first introduced into Malaysia in 1870. Like the coconut palm, the oil palm is grown mainly for its oil producing fruit. Owing to its commercial importance, the botanical and cultivation aspects of the oil palm have been extensively studied. Its two main products are palm oil and palm kernel oil. Traditionally, these products are used mainly in the manufacture of compound fat and soap, but now their usage has widened and varied considerably. Recently, much attention has been channeled toward finding suitable applications for oil palm industry by products. In the light of the scarcity of timber and different environmental issues, various types of by products have been studied to see whether they can serve as replacements for timber or alleviate environmental problems. At the palm oil mills the byproducts consists of shell, empty fruit bunch (EFB), presses fruit fibers (mesocarp fibers) and palm oil mill effluent (POME) .The chemical constituents and physical properties of the fibers are given in table 1.0 (Rozman et al ,2001).

Table 1.0: Properties of oil palm flour

Chemical constituents (%)	**Value**
Cellulose	78
Hemicellulose	10
Lignin	8
Wax	2
Ash content	1
Physical properties of oil palm fiber	**Value**
Diameter (μm)	150-500
Tensile strength (MPa)	248
Young's modulus (GPa)	3.2
Elongation at break (%)	25
Microfibrillar angle (°)	46

2.3 Matrix

The functions of a matrix, the binder material, whether organic, ceramic or metallic, are to support and protect the fillers, the principal load carrying agent, and to provide a means of distributing the load among and transmitting it between the fillers without itself fracturing. When filler breaks, the load from one side of the broken filler is first transferred to the matrix and subsequently to the other side of the broken filler. Typically, the matrix has a considerably lower density, stiffness (modulus), and strength than those of the reinforcing filler material, but the combination of the two main constituents (matrix and filler) produces high strength and stiffness, while still possessing a relatively low density. The matrix used in composites is classified as under:

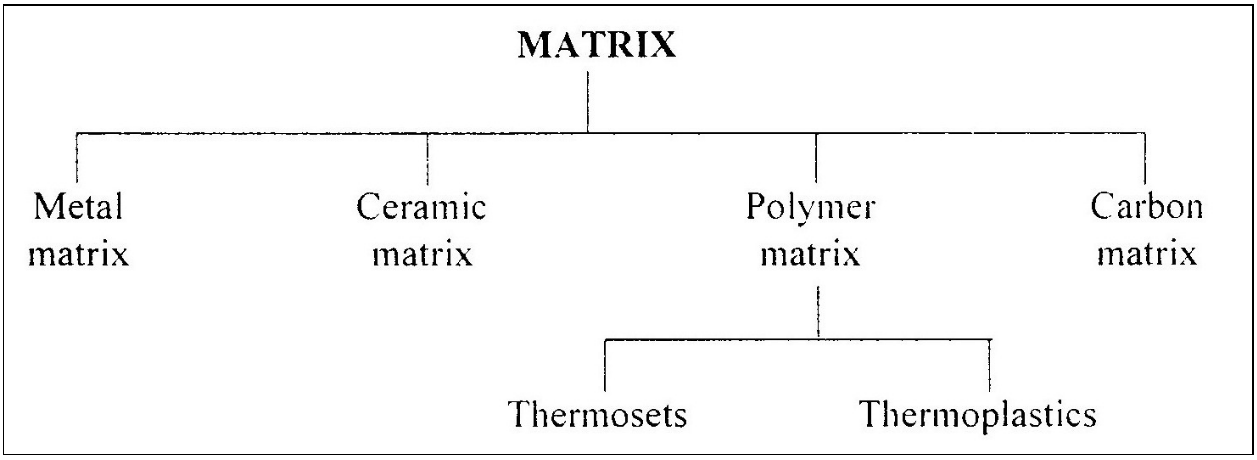


Figure 2.3: Classification of matrix

Polymer matrix composite (PMC) is a composite material for which the matrix is a polymer resin, and having fibers (normally glass, carbon, or aramid) as the dispersed phase. Ceramic matrix composite (CMC) is a composite for both matrix and dispersed phases are ceramic materials. The dispersed phase is normally added to improve fracture toughness. Metal matrix composite (MMC) is a composite material that has a metal or metal alloy as the matrix phase. The dispersed phase may be particulates, fibers, or whiskers that normally are stiffer, stronger, and/or harder than the matrix . The composites performance is influenced by the following matrix properties:

• Elastic Constants
• Yield and ultimate strength under tension, compression or shear
• Failure strain of ductility
• Fracture toughness
• Resistance to chemicals and moisture
• Thermal and oxidative stability

When selecting a particular matrix for specific composite, application, service environment parameters such as temperature stress, moisture, chemical effects and possibly radiation damage must be considered. The possibility and the processing history of the matrix must be taken into account.

2.4 Fiber Matrix Composites

Of all composite material, the fiber type specifically the inclusion of fibers in a matrix has evoked the most interest among engineers concerned with structural applications. Initially most work was done with strong, stiff fibers of solid, circular cross section in a much weaker, more flexible matrix, i.e., glass fibers in synthetic resins. Then development work disclosed the special advantages offered by metal and ceramic fibers, hollow fibers, fibers of noncircular cross section and stronger, stiffer and more heat resistant matrices.

2.5 Fillers

Fillers are used in polymer for a variety of the reasons such as cost reduction, improved processing, density control, optical effects, thermal conductivity, and control of thermal expansion, electrical properties, magnetic properties, flame retardancy and improved mechanical properties such as hardness and tear resistance. Each filler type has different properties and these in turn are influenced by the particle size, shape and surface chemistry. Filler characteristics are discussed from costs to particle morphology. Particle specific surface area and packing are important aspects. Practical aspects of filler grading are described. For example, the use of and average particle size on data sheets can be misleading as it may not accurately reflect particle size distribution. Different measuring conditions can also give rise to variations in apparent particle size. The principal filler types are outlined. These include carbon black, natural mineral fillers and synthetic mineral fillers (Rozman et al ,2001).Filler surface modification is an important topic. Most particulate fillers are inorganic and polar, which can give rise to poor compatibility with hydrocarbon polymers and processing problems, among other effects. The main types of the modifying agent and their uses are described, from fatty acids to functionalized polymers. Fillers are also discussed in relation to different polymer types. For example, in flexible PVC because of the plasticizer, the filler has little effect on processing. This allows relatively high filler levels to be incorporated. Modification of the interphase region between filler and matrix means that the interphase transfers the applied load from the matrix to the filler. In highly filled composites the interphase determines the properties of the composite. There is also a reduction in the adsorption/deactivation of the key face additives such as antioxidants and durative. There are three types of interactions when considering filler surface treatments. Firstly, interaction between the surface modifier molecule and the filler surface must usually be strong for all types of surface modifier. In most cases this is a chemical bond, which is a carboxylate linkage with a fatty acid, or strong hydrogen bond. There is also interaction between the adsorbed and non-adsorbed surface modifier and the polymer matrix. If this interaction is weak through dispersion forces, but the filler surface polarity is modified so that it matches that of the polymer matrix, then there is a noninteracting, dispersant type treatment. If this interaction is strong then a coupling agent is defined. The third type of interaction is a mutual one between the absorbed and non absorbed surface modifier molecules. If the second and third types of interaction are strong, then the treatment system is a reactive coupling or interacting one. There are two main methods of surface treatment addition. The filler may be pretreated where the surface treatment is pre-adsorbed onto the filler surface before incorporation into the matrix. However, some types of surface treatment are best added directly to the pre-mix of filler and matrix, prior to melt blending. This is known as in-situ treatment. The surface treatment then diffuses to the filler surface through the polymer matrix melt. Fillers are divided into 73 groups and their properties are analyzed. These groups include a full variety of products used by today’s industry to change optical properties and color, improve surface characteristics and dimensional stability, change thermal, magnetic and electrical properties, improve mechanical properties, durability, and rheology, affect chemical reactivity, biodegradability and performance of other additives (HPS Abdul khalil et,. 2001).

2.6 Thermosetting Plastic

Thermoset formed into a permanent shape and cured or “set” by chemical reaction cannot be remelted and reformed into another shape but degrade or decompose upon being heated too high a temperature. Thus, thermosets cannot be recycled. The term Thermosetting implies that heat is required to permanently set the plastic. There are, however, many so called thermosets that set or cure at room temperature by a chemical reaction only. Most thermosets consist of a network of carbon atoms covalently bonded to form a rigid solid. Sometimes nitrogen, oxygen, sulfur, or other atoms are also covalently bonded into a thermoset network structure (HPS Abdul khalil et,. 2001)].

2.7 Natural Fiber Filled Polymer Composite

Natural fiber filled polymer composites is material that have natural fiber as the matrix in the composites. Natural fibers were added into the composite to reinforcing the composites. An example of natural fiber is bamboo, wood, kenaf, cotton, coconut husk,oil palm, jute, areca fruit and many more. Fibers or fibers are a class of hair-like materials that are continuous filaments or are in discrete elongated pieces, similar to pieces of thread. They can be spun into filaments, thread, or rope. They can be used as a component of composite materials. They can also be matted into sheets to make products such as paper or felt. Fibers are of two types that is natural fiber and manmade or synthetic fiber. Natural fibers include those made from plant, animal and mineral sources. Natural fibers can be classified according to their origin. Vegetables fibers are generally comprised mainly of cellulose for examples include cotton, linen, jute, flax, ramie, sisal, and hemp. Cellulose fibers serve in the manufacture of paper and cloth. Animal fibers generally comprise proteins; examples include silk, wool, angora, mohair and alpaca. Mineral fibers are naturally occurring fiber or slightly modified fiber procured from minerals. These can be categorized such as asbestos is the only naturally occurring mineral fiber. Varietions are serpentine (chrysotile) and amphiboles (amosite, crocidolite, tremolite, actinolite, and anthopillte). Ceramic fibers such as glass fibers (glass wool and quartz), aluminum oxide, silicon carbide, and boron carbide and metal fibers such as aluminum fibers (HPS Abdul khalil et,. 2001).

2.8 Lignocellulosic

Lignocellulosic materials, which predominantly consist of cellulose, lignin and hemicellulose, in the production of the plastic composites has gained momentum in recent years. Lignocellulosic materials, especially wood, have stimulated much interesting the manufacture of composites during the past decade, i.e., used as filler material instead of conventional filler such as mica, clay and glass fibers. In recent years, the search for appropriate utilization of lignocellulosic materials (other than wood) has been growing, either for replacing existing wood species in making conventional panel products or for producing plastic composites. The increasing trend in using these nonwood materials has been induced by growing demand for lightweight, high performance materials in an age of diminishing natural fiber resources (wood in particular) and escalating raw materials and energy. Thus, the prospect of using oil palm by products in various products is increasingly bright in the light of the demand for lignocellulosic materials in vast areas of applications. In general, the utilization of lignocellulosic material in the production of plastic composites is becoming more attractive, particularly for low cost/ high volume applications. There are several factors responsible for the observed trend. Lignocellulosic derived fillers possess several advantages compared to inorganic fillers, i.e., lower density, greater deformability, less abrasiveness to equipment, and lower cost. More importantly, lignocellulosic based fillers are derived from a renewable resource, available in relative abundance, of which the potential has not been really tapped. Lignocellulosic materials including wood and oil palm by products such as empty fruit bunch (EFB) have significantly lower density than the common inorganic fillers. Thus, specific mechanical properties (strength to weight ratio) of these lignocellulosic plastic composites, in addition to those characteristics mentioned before, often exceed those of other filled plastic owing to this favorable density difference. Lignocellulosic- polypropylene composites have complex morphologies that influence their behavior (HPS Abdul khalil et,. 2001).

Table 2.8: The properties of several commonly used in engineering materials

Material	Insulator	Strength to Weight Ratio	Thermal	UV Light	Acid	Swelling	Determination
Ligno-cellulosic	Good	High	Yes (fire)	Yes[a]	Yes[b]	Yes (moisture)	Yes[c]
Metals	Poor	Low	Yes (melt)	No	Yes	Yes (temp)	Yes[b]
Plastics	Poor to good	Fair	Yes (fire)	Yes/ No	Yes/ No	Yes (temp)	No
Glass	Poor	Low	Yes (melt)	No	No	Yes (temp)	No
Concrete	Poor	Low	No	No	Yes	No	Yes[d]

a Limited to surface

b Oxidation

c Caused by organisms

d Caused by moisture

Wood and other lignocellulosics swell as a result of moisture but metals, plastics and glass also swell as a result of increases in temperature. Lignocellulosic are not the only substances that decay. Metal oxidize and concrete deteriorates as a result of moisture, pH changes and microbial action. Lignocellulosic and plastic burn but metal and glass melt and flow at high temperatures. Lignocellulosic are excellent insulating substances, the insulating capacity of other materials ranges from poor to good. Furthermore, the strength to weight ratio is very high for lignocellulosic fibers when compared to that for almost every other fiber. Given these properties, lignocellulosics compare favorably to other products (HPS Abdul khalil et,. 2001).

2.9 Advantages of Natural Fiber Filled Polymer Composite

The primary advantage claimed for these composite products are low maintenance, uniformity in properties and performance and longevity (HPS Abdul khalil et,. 2001). The advantage of the natural fiber filled polymer composite is corrosion resistance, fatigue resistance, electrical Isolation.

2.10 Disadvantages of Natural Fiber Filled Polymer Composite

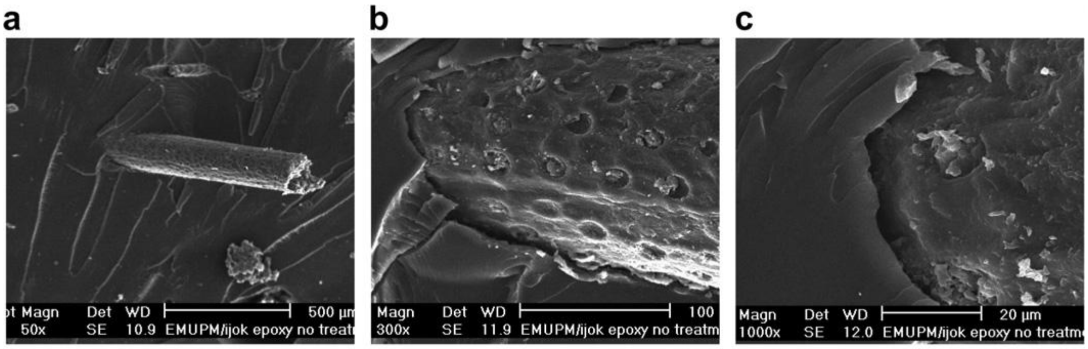
The disadvantages of the natural fiber filled polymer composite are their relatively low structural properties compared to those of structural lumber, which have limited their use to nonstructural or semi-structural application such as landscaping, piers and docks, wall panels and outdoor furniture (HPS Abdul khalil et,. 2001).

2.11 Application of Natural Fiber Filled Polymer Composite

The application of the natural fiber filled polymer composite is suitable for to made aero plane wings, space application, sporting equipment, ship building, energy technologies such as wind turbine rotor blade, wind tunnel fan, filament winding, fabric winding on mandrel, pultrusion (Rozman et al,. 2001).

2.12 Alkaline treatment

The alkaline treatment has significantly improved the tensile properties of sugar palm fibre reinforced epoxy composites particularly for tensile modulus. The hydrophilic nature of sugar palm fibre has been reduced due to this treatment and therefore has increased the interfacial bonding between matrix and fibres. However, at higher soaking times and alkaline concentrations, the effect of these parameters on tensile strength is not so pronounced because at these conditions, fibre damages may have been dominant (D. Bachtiar et al. 2008).



50x magnification **300x magnification** **1000x magnification**

Figure 2.12: SEM micrographs for untreated sugar palm fibre reinforced epoxy composite fracture after tensile loading

SEM micrographs for the composites after alkali treatment are shown in Figs. 8 and 9 for 300· magnifications. Fig. 8a shows the SEM micrograph for treated 0.25 M NaOH sugar palm fibre reinforced epoxy composite fracture after tensile loading for 1 h soaking time. The average of tensile strength is 49.875 MPa, which there is the increase of 16.4% from untreated fibre composite. The figure shows a significantly good bonding between fibre and matrix. The surface of fibre is seen rougher than untreated fibre composite sample and it may be attributed to the enhancement of the bonding strength between fibre and matrix (D. Bachtiar et al. 2008).